# LEARNING BIOLOGY THROUGH AN INQUIRY-BASED APPROACH: AN OVERVIEW OF BENEFITS AND CHALLENGES

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**Abstract**

*The paper advocated for the adoption of inquiry-based learning (IBL) as a central instructional strategy in Biology education at the secondary and tertiary levels. Traditional teacher-centered methods often limited students' engagement and critical thinking, whereas IBL fostered deeper conceptual understanding, scientific inquiry, and lifelong learning. Grounded in constructivist, sociocultural, and pragmatic educational theories, IBL emphasized active exploration, collaboration, and reflection. The paper highlighted the pedagogical benefits of IBL, such as enhanced scientific reasoning, motivation, and the development of 21st-century skills. Despite challenges like time constraints and the need for skilled facilitation, the long-term gains in student competence and scientific literacy made IBL a valuable approach. Ultimately, the paper suggested that Biology and other science educators and policymakers should prioritize IBL, as the approach better aligned science teaching with the nature of scientific practice and the needs of modern learners.*

***Keywords:*** Inquiry-based, learning, Biology, science education

## Introduction

The teaching of Biology at both secondary and post-secondary levels has long been dominated by rote learning and teacher-centered methods. With the growing need to cultivate critical thinking and scientific literacy, inquiry-based learning (IBL) has gained recognition as a more effective approach. This paper advocates for the integration of IBL as a central instructional model in Biology education, emphasizing its ability to promote deeper conceptual understanding, the development of scientific skills, and a sustained curiosity for learning (National Research Council, 2000).

Based on John Dewey's philosophy, education begins with the learner's curiosity. In the classroom, inquiry places the responsibility for learning on the students and encourages them to construct their own understanding of concepts. Lee et al. (2006) define inquiry-based learning as "an array of classroom practices that promote student learning through guided and increasingly independent investigation of complex questions and problems, often for which there is no single answer." Through this approach, students are supported in developing essential skills such as asking meaningful questions, identifying what needs to be learned and the resources required, and effectively communicating their learning with others.

According to Queen's University's Centre for Teaching and Learning (n.d.), inquiry learning represents a progressively independent process of growth. Students develop skills in various aspects of the inquiry process over time. At introductory stages, instructors may provide extensive guidance and facilitation, while advanced courses gradually expand to incorporate all four elements of inquiry, allowing students to take greater ownership of their learning. The four elements are as follows:

i. Asking and refining questions
ii. Research & reflecting: identifying and accessing resources
iii. Evaluate: assessing whether findings addressing the questions and raise new ones
iv. Construct: synthesizing new understandings

**The Role of IBL to Improve Science Teacher's Pedagogical Practices**

In science, and Biology in particular, students are expected to develop the ability to gather, analyze, interpret, and synthesize information through classroom activities (Shaheen & Kayani, 2015). According to Gehring and Eastman (2008), the subject mirrors fundamental issues that influence daily life in society, making it essential for students to acquire skills that enable them to address real-life challenges. Ünlü and Dökme (2020) emphasized that such competencies can be achieved through active learning strategies like inquiry-based learning (IBL), which fosters the acquisition of process, procedural, and conceptual knowledge critical for societal advancement. Through IBL, Biology students gain the confidence to investigate biological processes independently and draw meaningful, practical conclusions applicable not only in the classroom but also in broader school and societal contexts (Akuma & Callaghan, 2019).

Research has shown that IBL approaches are beneficial across multiple settings. Studies consistently highlight that IBL strengthens students' understanding of the role and process of scientific inquiry. For example, Mohammed et al. (2020) found that incorporating IBL in science instruction effectively supports learning outcomes across diverse contexts, disciplines, and educational levels, from primary to tertiary. This effectiveness stems from its foundation in social constructivism, which actively engages learners in exploring knowledge sources. Likewise, Chairam, Klahan, and Coll (2015) noted that inquiry-based instruction not only helps students feel comfortable and enjoy their learning experiences but also enhances their scientific skills and competences, which are transferable to all aspects of life.

**Theoretical Foundations of Inquiry-Based Learning**

The transition from teacher-centered instruction to learner-centered pedagogies has sparked increasing interest in inquiry-based learning (IBL) as a key educational approach. Grounded in constructivist theories, IBL highlights the learner's active involvement in constructing knowledge. Instead of simply absorbing information, students are encouraged to question, investigate, and reflect, thereby simulating the practices of scientists and researchers. For educators and curriculum designers, understanding the theoretical foundations of IBL is essential to cultivating critical thinking, problem-solving abilities, and lifelong learning. This section examines the major educational theories and scholars that form the basis of IBL.

1. **Constructivism (Jean Piaget, Jerome Bruner):** Inquiry-Based Learning (IBL) is rooted in constructivist theory, which argues that learners actively build new knowledge by connecting it to what they already know. Piaget (1972) explained that learning develops through the processes of assimilation and accommodation across different stages of cognitive growth. Similarly, Bruner (1961) introduced the idea of a spiral curriculum, in which students revisit concepts at progressively deeper levels of inquiry.
2. **Sociocultural Theory (Lev Vygotsky)**: Vygotsky's (1978) notion of the Zone of Proximal Development (ZPD) reinforces IBL by stressing the importance of social interaction and scaffolding. With guidance from teachers and peers, learners are able to engage in inquiry tasks that would be difficult to complete independently.

3. **Pragmatism (John Dewey)**: Dewey (1938) emphasized experiential learning, arguing that education should stem from meaningful experiences. He believed that real-life problem-solving and hands-on activities driven by curiosity and reflection provide the most effective pathway for student learning.

**Key Features of Inquiry-Based Learning**

i. Inquiry-based learning (IBL) is rooted in constructivist educational theory, which highlights the active role of learners in constructing knowledge. Unlike traditional lecture-based instruction, IBL engages students directly in the learning process through questioning, investigation, collaboration, and reflection. In science education, several core features characterize effective inquiry-based instruction:

ii. Question-driven: Learning is initiated by meaningful questions posed by students or guided by teachers.

iii. Active exploration: Students participate in hands-on experiments, research, or problem-solving activities.

iv. Critical thinking: Emphasis is placed on analyzing, synthesizing, and evaluating information.

v. Collaboration: Group discussions, teamwork, and shared projects play a central role in knowledge building.

vi. Reflection: Learners regularly review their processes and outcomes to deepen understanding.

vii. These elements collectively ensure that inquiry-based learning fosters deeper engagement and more authentic scientific practices (Helmo-Silver, Duncan, & Chinn, 2007).

**Phases of Inquiry-Based Learning (Based on Pedagogical Models)**

i. **Orientation and Engagement** – At this stage, learners are introduced to a topic or problem in a way that stimulates curiosity and links new ideas to their prior knowledge.

ii. **Question Formulation** – Students, with or without teacher guidance, generate thought-provoking questions that will shape and direct the inquiry process.

iii. **Investigation and Exploration** – Learners actively seek answers by gathering data, conducting experiments, or exploring relevant resources.

iv. **Analysis and Interpretation** – The collected information is carefully examined; students look for patterns, relationships, and meanings to deepen understanding.

v. **Conclusion and Communication** – Based on evidence, learners develop conclusions and communicate their findings through reports, presentations, or discussions.

vi. **Reflection and Evaluation** – Finally, students assess their learning, reflect on the inquiry process, and evaluate the effectiveness of strategies used. (Adapted from Pedaste et al., 2015)

**Benefits of Inquiry Based Learning ( IBL)**

i. **Promotes Deep Understanding and Retention of Content**: Scientific knowledge is not a static collection of facts but an evolving understanding derived from observation, experimentation, and reasoning. Inquiry-based learning replicates this process in the classroom, allowing students to engage with Biology as scientists do. According to National Research Council (2000), inquiry "requires students to identify assumptions, use critical and logical thinking, and consider alternative explanations." This approach mirrors the actual practices of scientific research, making learning authentic and meaningful.

ii. **Enhances Problem-Solving and Research Skills**: Research has shown that students involved in inquiry-based Biology instruction perform better in terms of conceptual understanding and knowledge retention. For instance, Minner, Levy, and Century (2010) found that students in inquiry-based science classes showed improvements in learning outcomes compared to those in traditional settings. By exploring biological phenomena themselves, students construct their own understanding rather than passively receiving information.

iii. **Fosters Independent Learning and Intrinsic Motivation**: Inquiry-based learning supports student motivation through active participation and personal

ownership of learning tasks. When learners pose questions, design experiments, and interpret results, they feel more connected to the content. Hmelo-Silver, Duncan, and Chinn (2007) emphasize that such engagement not only motivates learners but also helps them develop inquiry habits of mind, such as perseverance, curiosity, and reflection.

iv. **Prepares Students For Real-world Challenges**: Beyond biological content, inquiry-based learning cultivates transferable skills such as problem-solving, communication, collaboration, and data analysis. These skills are crucial in preparing students for a dynamic, knowledge-based society. As noted by Bybee (2014), inquiry-based science education helps students become informed citizens capable of making evidence-based decisions on issues such as climate change, health, and biotechnology.

**Challenges of Inquiry Based Learning (IBL)**

1. **Time-Intensive Nature:** IBL requires ample time for students to develop questions, investigate topics, and reflect on their findings. This time demand can conflict with rigid curricula, especially in systems dominated by standardized testing (Hmelo-Silver et al., 2007).
2. **Teacher's Expertise and Training:** Effective IBL facilitation demands teachers who can skillfully guide inquiry without dictating it. However, many educators lack the necessary training in inquiry pedagogy and classroom strategies, limiting the quality of implementation (Crawford, 2007).
3. **Student's Readiness:** Not all students possess the prior knowledge, self-discipline, or critical thinking skills needed for self-directed learning. Without appropriate support, they may feel overwhelmed or disengaged (Bell et al., 2010).
4. **Resource Limitations:** IBL often depends on access to diverse materials, laboratory equipment, digital tools, or real-world data—resources that may be scarce in underfunded or rural schools (Prince & Felder, 2007).
5. **Assessment Difficulties:** IBL emphasizes skills like collaboration, analysis, and problem-solving, which are difficult to measure with conventional assessments. Traditional grading systems may not accurately reflect the depth of learning in inquiry tasks (Asay & Orgill, 2010).

6. **Unequal Participation:** In group-based inquiries, dominant students may take over while others contribute less, leading to unequal learning experiences. Teachers must actively monitor group dynamics to ensure fair participation (Barron & Darling-Hammond, 2008).
7. **Resistance to Change:** Students and parents accustomed to traditional, lecture-based education may resist IBL due to its open-ended and less predictable structure. This cultural resistance can slow down adoption (Windschitl, 2003).
8. **Need for Scaffolding:** Students often require structured guidance to develop meaningful, focused questions. Without scaffolding, they may pursue irrelevant or overly broad topics, leading to shallow or unfocused inquiry outcomes (Hmelo-Silver et al., 2007).

The Inquiry-based Learning Model emerged in the 1960s, during the "discovery learning" movement and relies upon the idea that individuals are able to learn by investigating scenarios and problems, and through social experiences. Rather than having to memorize information from printed materials, instructors encouraged their students to conduct investigations that would satisfy their curiosity, help them broaden their knowledge base and develop their skills and mental frames. It's important to remember that inquiry-based learning is not a technique or practice per se, but a process that has the potential to increase the intellectual engagement and deep understanding of learners, urging them to:

1. Develop their questioning, research and communication skills
2. Collaborate outside the classroom
3. Solve problems, create solutions, and tackle real-life questions and issues
4. Participate in the creation and amelioration of ideas and knowledge. ( Pedaste et al., 2015).

**Counterargument and Rebuttal**

Critics of inquiry-based learning often point to practical challenges such as time constraints, assessment difficulties, and the need for extensive teacher preparation (Kirschner, Sweller, & Clark, 2006). However, these challenges can be addressed through professional development, curriculum redesign, and the integration of blended learning tools. Moreover, the long-term

benefits of inquiry — deeper learning, skill development, and scientific literacy — outweigh the initial investment required for implementation.

**Conclusion**

In conclusion, inquiry-based learning offers a transformative approach to Biology education by making learning more interactive, reflective, and aligned with scientific practice. It nurtures critical thinking, fosters engagement, and equips students with essential life skills. Therefore, educators and policymakers should promote and support the integration of inquiry-based strategies into Biology curricula to prepare learners for the demands of the 21st century.

**Suggestions**

1. Curriculum developers should revise existing science syllabi to incorporate inquiry based methods that emphasize students led, investigation.
2. Ministries of education and teacher training institutions should prioritize workshops, seminars, and continuous professional development programs to equip Biology teachers with the skills to design and facilitate inquiry based lessons.
3. Government and school administrators should allocate adequate resources , such as science kits, lab equipment, and digital tools to support active learning and experimentation even in both rural and urban under-resourced schools.
4. Biology teachers should relate inquiry projects to local, real life biological issues (eg. Climate change, Health, Agriculture, or Sanitation) to make learning more relevant, engaging, and practical for students.
5. Examination bodies should include inquiry compatible assessment such as projects work, science investigations and oral or written reports that evaluate students' research analysis, and problem solving skills not just memorization.

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